Fishery Data Series No. 10-37

Chinook Salmon Escapement in the Gulkana River, 2005-2006

by

James W. Savereide

May 2010

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	\$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye to fork	MEF
mideye to tail fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$log_{2,}$ etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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James W. Savereide

Division of Sport Fish, Fairbanks

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

May 2010

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James W. Savereide,
Alaska Department of Fish and Game, Division of Sport Fish
1300 College Road, Fairbanks, AK 99701-1599, USA

This document should be cited as:
Savereide, J. W. 2010. Chinook salmon escapement in the Gulkana River, 2005-2006. Alaska Department of Fish and Game, Fishery Data Series No. 10-37, Anchorage.

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ABSTRACT

Counting tower techniques were used on the Gulkana River to estimate the escapement of Chinook salmon Oncorhynchus tshawytscha upstream of the West Fork Gulkana River in 2005 and 2006. The Gulkana River counting tower was in operation from 28 May through 15 August 2005 and from 3 June through 15 August 2006. These periods accounted for the entire Chinook salmon run and a portion of the sockeye salmon run. Adverse weather resulted in inadequate viewing conditions for 3 d in 2005 and 13 d in 2006. The estimated Chinook salmon escapement was 2,718 (SE = 174) in 2005 and 4,846 (SE = 279) in 2006. During the periods of poor visibility, passage was interpolated with one of two methods depending upon the length of time counts that were missed. Interpolated estimates of daily passage for days when visibility precluded counting represented 4.4% of the total escapement estimate in 2005 and 29.9% of the total estimate in 2006. The estimated sockeye salmon O. nerka minimum escapements were 13,695 (SE=539) in 2005 and 41,919 (SE=2,889) in 2006. The first Chinook salmon were observed on 3 June 2005 and 12 June 2006 and upstream passage was considered complete on 5 August 2005 and 6 August 2006. In 2005, median date of passage occurred on 26 June and date of 75% passage was 9 July. In 2006, median date of passage was 8 July and date of 75% passage was 15 July.

Key words: Chinook salmon, *Oncorhynchus tshawytscha*, sockeye salmon, *O. nerka*, Copper River, Gulkana River, counting tower, escapement.

INTRODUCTION

The Gulkana River supports spawning populations of Chinook salmon *Oncorhynchus tshawytscha* and sockeye salmon *O. nerka*, rainbow/steelhead trout *O. mykiss*, and Arctic grayling *Thymallus arcticus*. The mainstem river is fed by the East Fork, Middle Fork, and West Fork Gulkana rivers (Figure 1). The river is one of six major spawning tributaries for Chinook salmon in the Copper River drainage and it supports the largest Chinook salmon sport fishery, with annual catch and harvest numbers accounting for over half of the Chinook salmon sport fishery in the Upper Copper Upper Susitna Management Area (UCUSMA; Taube 2006). In addition to the inriver sport fishery, the Gulkana River Chinook salmon stock is subject to harvest in commercial and subsistence fisheries located near the mouth of the Copper River and subsistence and personal-use fisheries located in the mainstem of the Copper River. Similar to the Gulkana River sport harvest, these mixed-stock fisheries have also shown an overall increase in harvest over the past 30 years (Ashe et al. 2005; Taube 2006).

The Alaska Department of Fish and Game (ADF&G) established a sustainable escapement goal (SEG) of 24,000 or more Chinook salmon for the Copper River drainage. Inriver abundance is estimated annually and inriver harvest is subtracted post-season to obtain an estimate of drainage-wide escapement. There is no information available regarding stock-specific exploitation rates, and there are no established escapement goals for Chinook salmon in any of the Copper River tributaries.

The section of the Gulkana River upstream of Sourdough Landing (Figure 1) has been designated by the U.S. Congress as a “wild river”, which makes it part of the National Wild and Scenic Rivers System. The Bureau of Land Management (BLM) manages the adjacent lands along both banks within this area.

In 2002, a multi-year cooperative project was initiated between ADF&G and BLM to monitor Chinook salmon escapement on the Gulkana River. The Gulkana River was selected because this stock makes up a significant portion of the total Copper River escapement, it supports a substantial sport fishery, access is relatively good, and it is one of the few tributaries in the Copper River drainage supporting Chinook salmon that is not glacially occluded. The goal of this project was to collect long-term information on escapements to develop management guidelines to aid managers when making decisions about the Chinook salmon sport fishery and to establish an escapement goal.

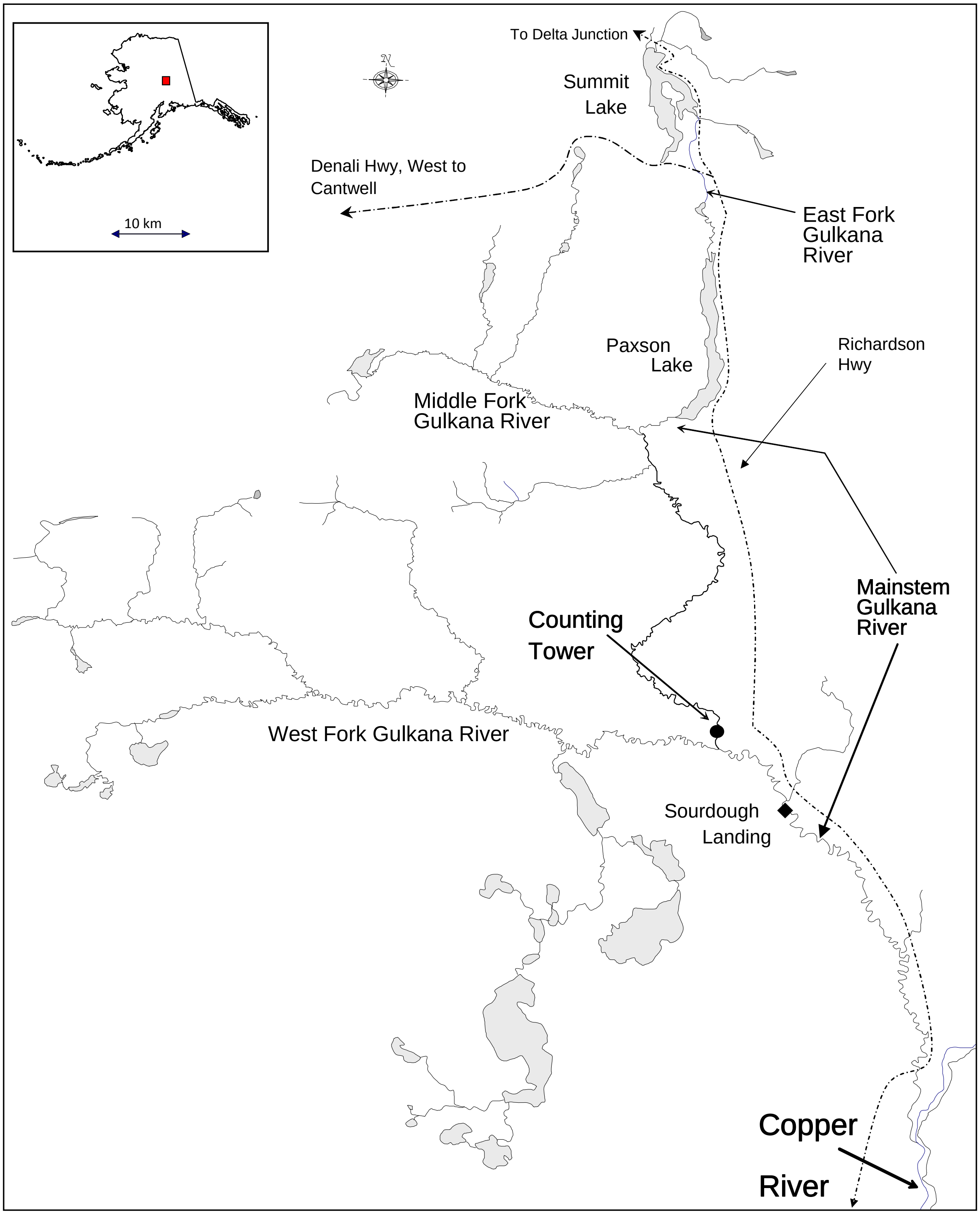

Figure 1.–The Gulkana River and location of the counting tower.

OBJECTIVES

In 2005 and 2006, the objective of this project was:

1. Estimate the escapement of Chinook salmon upstream of an established tower site on the mainstem Gulkana River, using counting tower techniques, such that the estimate was within 15% of the actual value 95% of the time.

In addition to the above objective, secondary tasks were:

1. Describe inriver run timing for Chinook and sockeye salmon in the Gulkana River; and,
2. Enumerate sockeye salmon passage at the counting tower during the period of tower operation.

METHODS

CHINOOK SALMON ESCAPEMENT

The number of Chinook salmon returning to an index area in the mainstem Gulkana River was estimated using counting tower techniques. Anecdotal information from sport fishers and guides and the results from previous aerial surveys (Taube 2002) and radiotelemetry studies (Savereide 2005) indicated that the majority of spawning in the Gulkana River drainage occurred upstream of the selected tower site. Counting begins on or about 1 June and continues into August until there are five continuous days with no net upstream passage of Chinook salmon.

The estimated number of Chinook salmon that migrate past the counting tower is equal to escapement if there is no harvest upstream of the tower site. Even though this is not true, the harvest upstream of the tower was considered insignificant relative to the number of fish migrating past the counting tower and the uncertainty associated with the escapement estimate. To obtain information that supports this assumption, the Statewide Harvest Survey (SWHS; Jennings et al. 2010) was modified to delineate site locations between Paxson Lake and Sourdough Landing to identify the harvest occurring upstream of the counting tower.

The counting tower was located approximately 2.5 km upstream from the confluence of the West Fork and the mainstem river (Figure 1). This location was chosen because the majority of spawning occurs upstream of this site and to avoid the often turbid water input of the West Fork. A small island splits the mainstem into two channels at the tower site. Steel scaffolding towers approximately 4 m above the water were located on each side of the island to provide a comprehensive view of the entire river (approximately 30 m per channel). The towers supported dome-shaped pole frames that were covered on the top and three sides with camouflage-print tarps to prevent shadows on the water and to provide the observer with protection from wind and rain. Maximum depth in both channels ranged from 1 to 1.5 m.

To ensure migrating fish were clearly visible a continuous band of white vinyl panels, approximately 2 m wide, was anchored to the river bottom across each river channel. There was also a 2–3 m section of picket weir placed near the base of each tower to ensure no fish were able to pass undetected directly beneath the towers. To ensure optimal viewing conditions, the panels were cleaned of debris, silt, gravel, and fish carcasses between scheduled counts as necessary. During periods of low ambient light, exterior-grade floodlights were used to illuminate the panels across each channel. Once the lights were turned on, they remained on between counts to maintain consistent conditions until no longer needed. This was done to reduce any associated effect that lighting changes may have had on salmon passage.

Two 10-min counting periods (one per channel, 20 min total) were scheduled every hour, for 24 h each day. Each day was divided into three 8-h shifts. Shift I began at 0600 and ended at 1359; Shift II began at 1400 and ended at 2159 hour; Shift III began at 2200 hour and ended at 0559 hour. The 10-min count for the west channel began between the top of the hour and 10 min past, and the 10-min count for the east channel immediately followed.

Numbers of Chinook and sockeye salmon were tallied and recorded on data forms at the end of each 10-min counting period. Separate data forms were maintained for each day and channel. Passage (upstream and downstream) was recorded to provide a net upstream passage during each 10-min count. Passage was defined as migration across the full width of the vinyl panels. Technicians tallied every fish that moved upstream and downstream, regardless of whether it was suspected, or known, to be the same fish (such occurrences were noted in the comment column on the data form). The number of carcasses floating downstream was recorded in the comments column. In addition, at the beginning of each hour, water level (relative level on a staff gauge) and water clarity (Table 1) were recorded. Water temperature was recorded at the beginning of each 8-h shift. Conditions that might effect the counts (e.g., heavy rain or strong winds) and general observations were recorded in the comments column.

Milling of Chinook salmon around the tower leads to positive and negative counts near the end of the run that do not reflect net upstream passage. As a result, there is typically a net negative passage during the last five or more days of monitoring. The escapement estimates were based on data collected through the date judged to represent maximum upstream passage. After this date, nearly all passage over the panels was attributed to milling salmon.

Data Analysis

Estimates of Chinook salmon escapement were stratified by day. Daily estimates of escapement were a single-stage direct expansion from the 10-min counting periods. The 10-min counting periods were considered a systematic sample because the counting periods were not chosen randomly. Hourly count data were combined across channels before calculating estimates in order to account for the covariance between channel-specific hourly counts.

Table 1.–Water clarity classification scheme.

Rank	Description	Salmon Viewing	Water Condition
1	Excellent	All passing salmon are observable	Virtually no turbidity or glare, “drinking water” clarity; all routes of passage observable
2	Good	All passing salmon are observable	Minimal to very low levels of turbidity or glare; all routes of passage observable
3	Fair	All passing salmon are observable	Low to moderate levels of turbidity or glare; all routes of passage observable
4	Poor	Possible, but not likely, that some passing salmon may be missed	Moderate to high levels of turbidity or glare; a few likely routes of passage are partially obscured
5	Unobservable	Passing fish are not observable	High level of turbidity or glare; ALL routes of passage obscured

The formulas necessary to calculate escapement from counting tower data were taken directly or modified from those provided in Cochran (1977). Daily passage and its variance were estimated using one of three scenarios depending on water clarity conditions:

1. When water clarity was *excellent* to *poor* (rank 1–4) for all scheduled counts during a day, actual counts were expanded to estimate daily passage (equations 1–3); and,

2. When a *small portion* (defined below) of a day's counts were conducted under *very poor* or *unobservable* water clarity (rank 4.5 or 5), daily passage was estimated using a combination of expanded actual (equations 1–3) and interpolated (equations 1–4) counts; and, when *most or all* of a day's counts were conducted under *very poor* or *unobservable* water clarity (rank 4.5 or 5), passage for the entire day was interpolated (equations 5–6).

Scenario #1: For days when all counts were conducted under excellent to poor conditions, daily passage, $\hat{N}_d$, was calculated by expanding counts within a shift for day *d*:

$$\hat{N}_d = \frac{M_d}{m_d} \sum_{j=1}^{m_d} y_{dj} \quad . \qquad (1)$$

The period sampling is systematic, because the sample (or primary unit) has secondary units taken within every hour in a day (i.e., systematically throughout the day). As provided in Wolter (1985), the variance associated with periods was calculated as:

$$s_d^2 = \frac{1}{2(m_d - 1)} \sum_{j=2}^{m_d} \left(y_{dj} - y_{d(j-1)}\right)^2 . \qquad (2)$$

The variance for the expanded daily passage was estimated as:

$$\hat{V}\left(\hat{N}_d\right) = \left(1 - \frac{m_d}{M_d}\right) M_d^2 \frac{s_d^2}{m_d} \quad . \qquad (3$$

where:

d = day;

j = paired 10-min counting period (a paired 10-min counting period consists of the two 10-min counts, one per channel, during a given hour);

y = observed period count (both channels combined);

m = number of paired 10-min counting periods sampled;

M = total number of possible paired 10-min counting periods.

Since 2002, a distinct diurnal migratory pattern was observed that was consistent between both river channels throughout the span of the run (Taras and Sarafin 2005, Perry-Plake et al. 2007). For each year, a period of peak passage was defined as the shortest, continuous period of time that accounted for 80% of the seasonal passage of Chinook salmon. To be reliable, expansions based on the diurnal pattern must have at least some counts that were successfully completed during the period of peak passage.

Scenario #2: Analyses of data collected during the first year of the project (2002) indicated that interpolating for undercounts using a diurnal run-timing pattern yielded more accurate estimates of passage than using a direct expansion of the successful counts within 8-h shifts for that day (Taras and Sarafin 2005). Therefore, periods with very poor or unobservable counts of the number of fish observed, y_{dj}, were estimated using known counts for that day and the observed diurnal pattern (Figure 2).

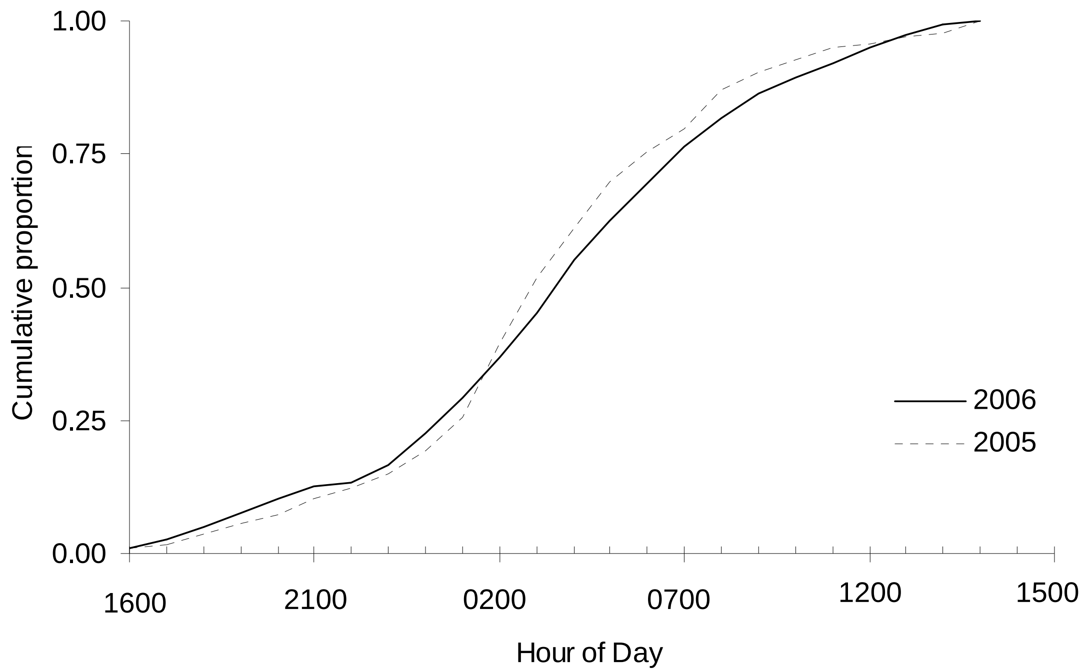

Figure 2.–Diurnal patterns for 2005 and 2006; the cumulative proportion of average daily counts by hour of day for Chinook salmon migrating past the Gulkana River counting tower. Note: a 'count day' is 1600 hours to 1500 hours (4:00PM to 3:00PM).

If counts were conducted successfully for a portion of the day that represents 25% or more of the expected passage for that day (as defined by the diurnal relationship), and if at least 25% of the periods during peak passage were successfully counted (scenario 2), then the channel-specific interpolated count was calculated as the product of the sum of successful counts for the day and the ratio of the expected daily passage not represented to the daily passage that was represented, or:

$$y_{dc,\text{interp}} = y_{dc,\text{actual}} \times \frac{1 - p_{edp}}{p_{edp}} \qquad (4)$$

where:

$y_{dc,\text{interp}}$ = interpolated sum of counts for missing (i.e. very poor or unobservable) 10-min periods by channel;

$y_{dc,\text{actual}}$ = daily sum of successful 10-min counts by channel; and,

p_{edp} = proportion of expected daily passage successfully counted.

The interpolated count was then allocated among missed 10-min counting periods based on the diurnal pattern for the current year. For example, if four 10-min counting periods were missed and the interpolated count for that period was 10 Chinook salmon, those 10 fish would be allocated to each of the missed periods in proportion to the diurnal pattern.

Daily abundance and variances were calculated using a combination of actual and interpolated counts. Treating interpolated counts as "known" would result in underestimating the daily variances. Therefore, daily variance estimates were inflated by decreasing the number of 10-min counting periods, m_d, sampled each day by the proportion of the expected daily passage successfully counted on that day. For example, if 85% of the expected run was successfully counted on a given day, then the adjusted m_d = 0.85 x m_d = 0.85 x 24. For the channel-combined counts the proportion successfully counted was the channel-specific proportions weighted by the proportion of the overall run passing each channel.

Although inflating the variance calculations guards against a negative bias in estimation of the total variance, this approach could still lead to unacceptably large biases if days with diurnal interpolations contribute substantially to the overall variance. Therefore, daily variances are estimated using this approach as long as interpolations using the diurnal pattern account for a small proportion of the total variance.

Scenario #3: If counts were conducted for a portion of the day that represented less than 25% of the expected passage for that day, or if less than 25% of the periods during peak passage were counted successfully, the moving average estimate for the missing day *i* was calculated as:

$$\hat{N}_i = \frac{\sum_{j=i-k}^{i+k} I(\text{successfull counts on day } j)\hat{N}_j}{\sum_{j=i-k}^{i+k} I(\text{successfull counts on day } j)} \quad (5)$$

where:

k = number of days missed due to adverse viewing conditions; and,

$$\mathrm{I}(\cdot) = \begin{cases} 1 & \text{when the condition is true} \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

is an indicator function.The interpolated values were used as the point estimates for the daily counts and the daily variation for undercounted days was the maximum variance of the *k* days before and the *k* days after the undercounted day *i*.

Total passage upstream of the counting tower and its associated variance incorporated all three daily passage estimation scenarios, and was estimated as (Cochran 1977):

$$\hat{N}_{PT} = \sum_{d=1}^{D} \hat{N}_d \text{ ; and,} \quad (7)$$

$$\hat{V}\left(\hat{N}_{PT}\right) = \sum_{d=1}^{D} \hat{V}(\hat{N}_d) \quad (8)$$

where:

D = total number of possible days.

SOCKEYE SALMON ESCAPEMENT

The number of sockeye salmon migrating past the counting tower was estimated using the methods described for estimating Chinook salmon escapement. Because the sockeye salmon run was known to continue after counting ceased, the escapement estimate reflects an unknown portion of the total run and can only be considered a minimum estimate of escapement.

RESULTS

CHINOOK SALMON ESCAPEMENT

In 2005, the Gulkana River counting tower was in operation from 28 May through 15 August. In 2006, the tower operated from 3 June through 15 August. Adverse weather resulted in less than favorable viewing conditions for 3 d in 2005 and 13 d in 2006 (Tables 2 and 3, Figure 3). The estimated Chinook salmon escapement was 2,718 (SE = 174) in 2005 and 4,846 (SE = 279) in 2006. Interpolated estimates of daily passage for days when visibility precluded counting represented 4.4% of the total escapement estimate in 2005 and 29.9% of the total estimate in 2006.

The first Chinook salmon were observed on 3 June 2005 and 12 June 2006 and upstream passage was considered complete on 5 August 2005 and 6 August 2006 (Figure 4). In 2005, median date of passage occurred on 26 June and date of 75% passage was 9 July. In 2006, median date of passage was 8 July and date of 75% passage was 15 July.

SOCKEYE SALMON ESCAPEMENT

The minimum escapement estimate for sockeye salmon was 13,695 (SE = 539) in 2005 and 41,919 (SE = 2,889) in 2006. The first sockeye salmon were observed on 4 June 2005 and 10 June 2006 (Tables 4 and 5).

Table 2.–Daily counts[a] and expanded counts, including interpolations[b], and the cumulative estimated escapement of Chinook salmon at the Gulkana River tower, 2005.

Date	East Channel		West Channel		Total		
	Daily Count	Daily Expanded/Interpolated	Daily Count	Daily Expanded/Interpolated	Daily Count	Daily Expanded/Interpolated	Cumulative Escapement
3-Jun	0	0	1	6	1	6	6
4-Jun	1	6	1	6	2	12	18
5-Jun	0	0	1	6	1	6	24
6-Jun	0	0	2	12	2	12	36
7-Jun	0	0	1	6	1	6	42
8-Jun	0	0	1	6	1	6	48
9-Jun	0	0	0	0	0	0	48
10-Jun	0	0	1	6	1	6	54
11-Jun	0	0	2	12	2	12	66
12-Jun	0	0	8	48	8	48	114
13-Jun	0	0	12	72	12	72	186
14-Jun	4	24	9	54	13	78	264
15-Jun	8	48	8	48	16	96	360
16-Jun	3	18	6	36	9	54	414
17-Jun	4	24	15	90	19	114	528
18-Jun	21	126	26	156	47	282	810
19-Jun	3	18	17	102	20	120	930
20-Jun	3	18	12	72	15	90	1,020
21-Jun	0	0	2	12	2	12	1,032
22-Jun	0	0	0	0	0	0	1,032
23-Jun	1	6	12	72	13	78	1,110
24-Jun	6	36	14	84	20	120	1,230
25-Jun	3	18	12	72	15	90	1,320
26-Jun	2	12	6	36	8	48	1,368
27-Jun	2	12	7	42	9	54	1,422
28-Jun	1	6	4	24	5	30	1,452
29-Jun	1	6	7	42	8	48	1,500
30-Jun	9	54	12	72	21	126	1,626
1-Jul	6	36	9	54	15	90	1,716
2-Jul	9	54	2	12	11	66	1,782
3-Jul	5	30	7	48	12	78	1,860
4-Jul	3	18	6	36	9	54	1,914
5-Jul	0	0	6	36	6	36	1,950
6-Jul	0	0	1	6	1	6	1,956
7-Jul	3	18	5	30	8	48	2,004
8-Jul	1	6	1	6	2	12	2,016
9-Jul	1	6	4	24	5	30	2,046
10-Jul	2	12	8	48	10	60	2,106

-continued-

Table 2.–Page 2 of 2.

Date	East Channel		West Channel		Total		Cumulative Escapement
	Daily Count	Daily Expanded/Interpolated	Daily Count	Daily Expanded/Interpolated	Daily Count	Daily Expanded/Interpolated	
11-Jul	2	12	1	6	3	18	2,124
12-Jul	0	0	1	6	1	6	2,130
13-Jul	3	18	4	24	7	42	2,172
14-Jul	0	0	5	30	5	30	2,202
15-Jul	0	0	1	6	1	6	2,208
16-Jul	2	12	6	36	8	48	2,256
17-Jul	0	0	4	24	4	24	2,280
18-Jul	1	6	1	6	2	12	2,292
19-Jul	0	0	3	18	3	18	2,310
20-Jul	2	12	3	18	5	30	2,340
21-Jul	0	0	1	6	1	6	2,346
22-Jul	0	0	4	24	4	24	2,370
23-Jul	1	6	2	12	3	18	2,388
24-Jul	3	18	3	18	6	36	2,424
25-Jul	1	6	1	6	2	12	2,436
26-Jul	1	6	3	18	4	24	2,460
27-Jul	1	6	1	6	2	12	2,472
28-Jul	3	18	9	54	12	72	2,544
29-Jul	2	12	-1	-6	1	6	2,550
30-Jul	1	6	4	24	5	30	2,580
31-Jul	1	6	2	18	3	***24***	2,604
1-Aug	1	3	4	15	5	***18***	2,622
2-Aug	0	0	2	12	2	12	2,634
3-Aug	4	24	1	6	5	30	2,664
4-Aug	4	24	2	12	6	36	2,700
5-Aug	1	6	2	12	3	18	2,718
6-Aug	0	0	-1	-6	-1	-6	2,712
7-Aug	0	0	1	6	1	6	2,718
8-Aug	-1	-6	-2	-12	-3	-18	2,700
9-Aug	3	18	-4	-24	-1	-6	2,694
10-	1	6	0	0	1	6	2,700
11-	-1	-6	1	6	0	0	2,700
12-	-1	-6	-2	-12	-3	-18	2,682
13-	-2	-12	-1	-6	-3	-18	2,664
Totals	136	813	317	1,905	453	2,718	2718

[a] To avoid splitting the diurnal pulses between adjacent calendar days a "count day" is defined as 1600 hours to 1500 hours; i.e. the 1 Aug count is passage that occurred from 1600 hrs 31Jul through 1500 hrs 1 Aug.

[b] Days for which interpolations were calculated are shaded and resulting changes in estimate numbers are shown in bold italics.

Table 3.–Daily counts[a] and expanded counts, including interpolations[b], and the cumulative estimated escapement of Chinook salmon at the Gulkana River tower, 2006.

	East Channel		West Channel		Total		
Date	Daily Count	Daily Expanded/Interpolated	Daily Count	Daily Expanded/Interpolated	Daily Count	Daily Expanded/Interpolated	Cumulative Escapement
3-Jun	0	0	0	0	0	0	0
4-Jun	0	0	0	0	0	0	0
5-Jun	0	0	0	0	0	0	0
6-Jun	0	0	0	0	0	0	0
7-Jun	0	0	0	0	0	0	0
8-Jun	0	0	0	0	0	0	0
9-Jun	0	0	0	0	0	0	0
10-Jun	0	0	0	0	0	0	0
11-Jun	0	0	0	0	0	0	0
12-Jun	0	0	1	6	1	6	6
13-Jun	0	0	3	18	3	18	24
14-Jun	0	0	6	36	6	36	60
15-Jun	2	12	5	30	7	42	102
16-Jun	0	0	4	24	4	24	126
17-Jun	1	6	2	12	3	18	144
18-Jun	2	12	12	72	14	84	228
19-Jun	***0***	***12***	***0***	***36***	***0***	***48***	276
20-Jun	***0***	***10***	***0***	***36***	***0***	***46***	322
21-Jun	***3***	***18***	***4***	***24***	***7***	***42***	364
22-Jun	0	0	2	12	2	12	376
23-Jun	1	6	0	0	1	6	382
24-Jun	***0***	***35***	***0***	***58***	***0***	***92***	474
25-Jun	***0***	***43***	***0***	***56***	***0***	***100***	574
26-Jun	***0***	***43***	***0***	***60***	***0***	***103***	677
27-Jun	***0***	***53***	***0***	***54***	***0***	***107***	784
28-Jun	***0***	***58***	***0***	***53***	***0***	***111***	896
29-Jun	***0***	***72***	***1***	***69***	***1***	***141***	1,036
30-Jun	***18***	***138***	***29***	***180***	***47***	***318***	1,354
1-Jul	9	54	11	66	20	120	1,474
2-Jul	7	42	13	78	20	120	1,594
3-Jul	19	114	3	18	22	132	1,726
4-Jul	9	54	***3***	***18***	***12***	***72***	1,798
5-Jul	16	96	20	120	36	216	2,014
6-Jul	10	60	***13***	***78***	***23***	***138***	2,152
7-Jul	3	18	13	78	16	96	2,248
8-Jul	12	72	23	138	35	210	2,458
9-Jul	2	12	8	48	10	60	2,518
10-Jul	5	30	11	66	16	96	2,614

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Table 3.–Page 2 of 2.

Date	East Channel Daily Count	East Channel Daily Expanded/Interpolated	West Channel Daily Count	West Channel Daily Expanded/Interpolated	Total Daily Count	Total Daily Expanded/Interpolated	Cumulative Escapement
11-Jul	7	42	18	108	25	150	2,764
12-Jul	7	42	31	186	38	228	2,992
13-Jul	7	42	24	144	31	186	3,178
14-Jul	19	114	43	258	62	372	3,550
15-Jul	1	6	17	102	18	108	3,658
16-Jul	1	6	2	12	3	18	3,676
17-Jul	1	6	4	24	5	30	3,706
18-Jul	2	12	12	72	14	84	3,790
19-Jul	0	0	3	18	3	18	3,808
20-Jul	0	0	***9***	***54***	***9***	***54***	3,862
21-Jul	0	0	4	24	4	24	3,886
22-Jul	0	0	4	24	4	24	3,910
23-Jul	1	6	2	12	3	18	3,928
24-Jul	7	42	15	90	22	132	4,060
25-Jul	9	54	0	0	9	54	4,114
26-Jul	4	24	2	12	6	36	4,150
27-Jul	1	6	9	54	10	60	4,210
28-Jul	7	42	6	36	13	78	4,288
29-Jul	11	66	5	30	16	96	4,384
30-Jul	4	24	4	24	8	48	4,432
31-Jul	9	54	9	*54*	18	*108*	4,540
1-Aug	5	30	1	*6*	6	*36*	4,576
2-Aug	7	42	0	0	7	42	4,618
3-Aug	9	54	2	12	11	66	4,684
4-Aug	5	30	-2	-12	3	18	4,702
5-Aug	9	54	10	60	19	114	4,816
6-Aug	4	24	1	6	5	30	4,846
7-Aug	-3	-18	-3	-18	-6	-36	4,810
8-Aug	3	18	1	6	4	24	4,834
9-Aug	3	18	-4	-24	-1	-6	4,828
10-Aug	3	18	-2	-12	1	6	4,834
11-Aug	0	0	-3	-18	-3	-18	4,816
12-Aug	-1	-6	0	0	-1	-6	4,810
13-Aug	0	0	-1	-6	-1	-6	4,804
14-Aug	-1	-6	-3	-18	-4	-24	4,780
Totals	256	1,892	422	2,954	678	4,846	***4,864***

[a] To avoid splitting the diurnal pulses between adjacent calendar days a "count day" is defined as 1600 hours to 1500 hours; i.e. the 1 Aug count is passage that occurred from 1600 hrs 31Jul through 1500 hrs 1 Aug.

[b] Days for which interpolations were calculated are shaded and resulting changes in estimate numbers are shown in bold italics.

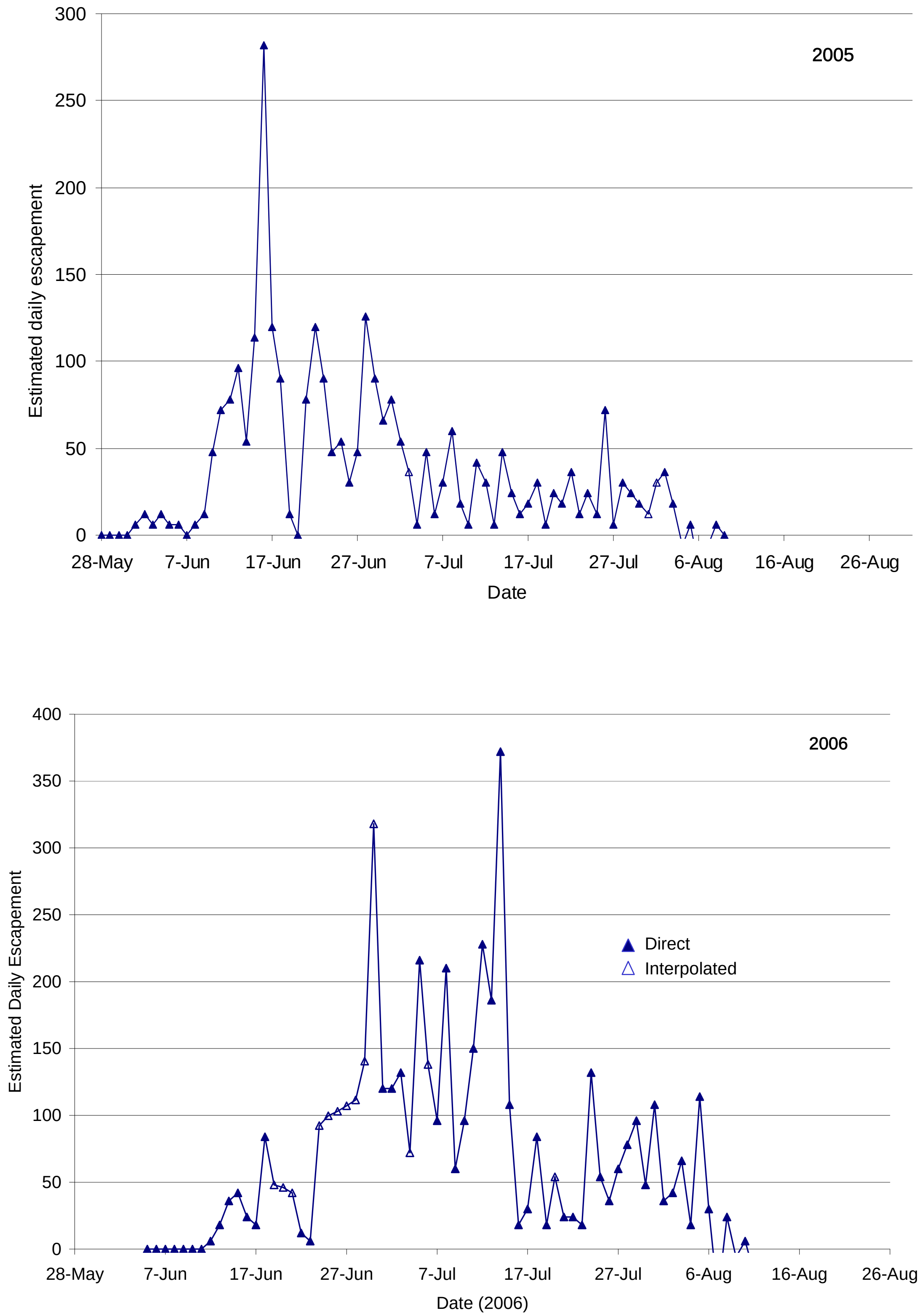

Figure 3.–Estimated daily escapement of Chinook salmon migrating past the Gulkana River counting tower in 2005 and 2006.

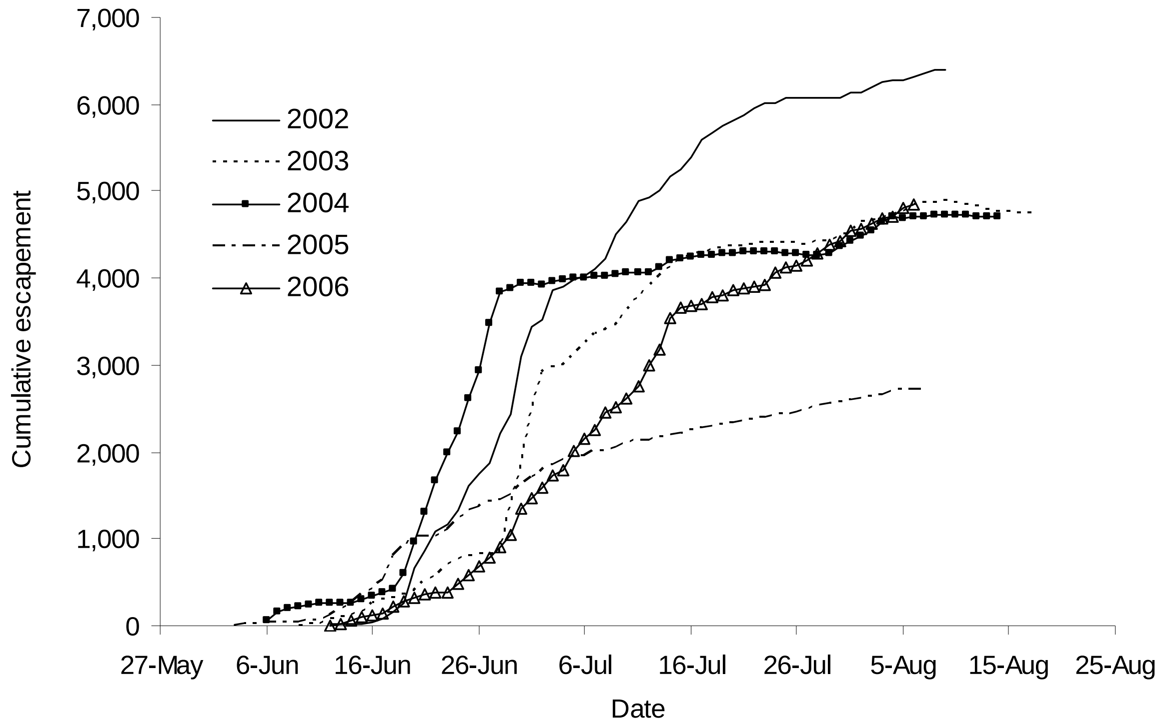

Figure 4.–Cumulative daily estimates, including interpolations, of Chinook salmon migrating past the Gulkana River counting tower, 2002–2006.

Table 4.–Daily counts[a] and expanded counts, including interpolations[b], and the cumulative estimated minimum escapement of sockeye salmon at the Gulkana River tower, 2005.

	East Channel		West Channel		Total		
Date	Daily Count	Daily Expanded/Interpolated	Daily Count	Daily Expanded/Interpolated	Daily Count	Daily Expanded/Interpolated	Cumulative Escapement
4-Jun	0	0	2	12	2	12	12
5-Jun	2	12	10	60	12	72	84
6-Jun	15	90	19	114	34	204	288
7-Jun	7	42	21	126	28	168	456
8-Jun	4	24	42	252	46	276	732
9-Jun	17	102	47	282	64	384	1,116
10-Jun	7	42	26	156	33	198	1,314
11-Jun	21	126	5	30	26	156	1,470
12-Jun	15	90	51	306	66	396	1,866
13-Jun	16	96	82	492	98	588	2,454
14-Jun	9	54	43	258	52	312	2,766
15-Jun	4	24	31	186	35	210	2,976
16-Jun	4	24	16	96	20	120	3,096
17-Jun	10	60	26	156	36	216	3,312
18-Jun	32	192	43	258	75	450	3,762
19-Jun	9	54	14	84	23	138	3,900
20-Jun	9	54	20	120	29	174	4,074
21-Jun	4	24	1	6	5	30	4,104
22-Jun	2	12	4	24	6	36	4,140
23-Jun	2	12	12	72	14	84	4,224
24-Jun	1	6	6	36	7	42	4,266
25-Jun	2	12	13	78	15	90	4,356
26-Jun	4	24	15	90	19	114	4,470
27-Jun	2	12	10	60	12	72	4,542
28-Jun	3	18	16	96	19	114	4,656
29-Jun	1	6	6	36	7	42	4,698
30-Jun	2	12	16	96	18	108	4,806
1-Jul	3	18	23	138	26	156	4,962
2-Jul	9	54	7	42	16	96	5,058
3-Jul	3	18	14	***90***	17	***108***	***5,166***
4-Jul	2	12	5	30	7	42	5,208
5-Jul	3	18	13	78	16	96	5,304
6-Jul	1	6	19	114	20	120	5,424
7-Jul	5	30	53	318	58	348	5,772
8-Jul	5	30	34	204	39	234	6,006
9-Jul	8	48	15	90	23	138	6,144
10-Jul	1	6	18	108	19	114	6,258
11-Jul	11	66	41	246	52	312	***6,570***

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Table 4.–Page 2 of 2.

Date	East Channel Daily Count	East Channel Daily Expanded/Interpolated	West Channel Daily Count	West Channel Daily Expanded/Interpolated	Total Daily Count	Total Daily Expanded/Interpolated	Cumulative Escapement
12-Jul	4	24	13	78	17	102	6,672
13-Jul	0	0	47	282	47	282	6,954
14-Jul	9	54	30	180	39	234	7,188
15-Jul	5	30	43	258	48	288	7,476
16-Jul	4	24	22	132	26	156	7,632
17-Jul	0	0	54	324	54	324	7,956
18-Jul	3	18	59	354	62	372	8,328
19-Jul	2	12	17	102	19	114	8,442
20-Jul	0	0	24	144	24	144	8,586
21-Jul	6	36	19	114	25	150	8,736
22-Jul	1	6	29	174	30	180	8,916
23-Jul	-1	-6	24	144	23	138	9,054
24-Jul	6	36	16	96	22	132	9,186
25-Jul	-1	-6	29	174	28	168	9,354
26-Jul	5	30	7	42	12	72	9,426
27-Jul	6	36	18	108	24	144	9,570
28-Jul	2	12	39	234	41	246	9,816
29-Jul	3	18	17	102	20	120	9,936
30-Jul	1	6	34	204	35	210	10,146
31-Jul	*2*	***18***	6	***48***	8	***66***	***10,212***
1-Aug	*0*	***15***	13	***84***	13	***99***	***10,311***
2-Aug	2	12	20	120	22	132	10,443
3-Aug	2	12	43	258	45	270	10,713
4-Aug	6	36	26	156	32	192	10,905
5-Aug	7	42	32	192	39	234	11,139
6-Aug	3	18	25	150	28	168	11,307
7-Aug	6	36	21	126	27	162	11,469
8-Aug	10	60	29	174	39	234	11,703
9-Aug	3	18	28	168	31	186	11,889
10-Aug	4	24	19	114	23	138	12,027
11-Aug	6	36	15	90	21	126	12,153
12-Aug	4	24	32	192	36	216	12,369
13-Aug	8	48	114	684	122	732	13,101
14-Aug	0	0	64	384	64	384	13,485
15-Aug	0	0	35	210	35	210	13,695
Totals	373	2,259	1,902	11,436	2,275	13,695	13,695

[a] To avoid splitting the diurnal pulses between adjacent calendar days a "count day" is defined as 1600 hours to 1500 hours; i.e. the 1 Aug count is passage that occurred from 1600 hrs 31Jul through 1500 hrs 1 Aug.

[b] Days for which interpolations were calculated are shaded and resulting changes in estimate numbers are shown in bold italics.

Table 5.–Daily counts[a] and expanded counts, including interpolations[b], and the cumulative estimated minimum escapement of sockeye salmon at the Gulkana River tower, 2006.

	East Channel		West Channel		Total		
Date	Daily Count	Daily Expanded/Interpolated	Daily Count	Daily Expanded/Interpolated	Daily Count	Daily Expanded/Interpolated	Cumulative Escapement
10-Jun	0	0	1	6	1	6	6
11-Jun	2	12	23	138	25	150	156
12-Jun	26	156	88	528	114	684	840
13-Jun	16	96	114	684	130	780	1,620
14-Jun	36	216	187	1,122	223	1,338	2,958
15-Jun	258	1,548	311	1,866	569	3,414	6,372
16-Jun	129	774	375	2,250	504	3,024	9,396
17-Jun	73	438	300	1,800	373	2,238	11,634
18-Jun	175	1,050	418	2,508	593	3,558	15,192
19-Jun	***0***	***608***	***0***	***1,566***	***0***	***2,174***	***17,366***
20-Jun	***0***	***494***	***0***	***1,114***	***0***	***1,608***	***18,974***
21-Jun	***40***	***336***	***53***	***390***	***93***	***726***	***19,700***
22-Jun	16	96	74	444	90	540	20,240
23-Jun	4	24	26	156	30	180	20,420
24-Jun	***0***	***377***	***0***	***715***	***0***	***1,092***	***21,512***
25-Jun	***0***	***180***	***0***	***220***	***0***	***400***	***21,912***
26-Jun	***0***	***157***	***0***	***194***	***0***	***351***	***22,263***
27-Jun	***0***	***184***	***0***	***172***	***0***	***357***	***22,619***
28-Jun	***0***	***309***	***0***	***118***	***0***	***428***	***23,047***
29-Jun	***0***	***436***	***0***	***303***	***0***	***740***	***23,787***
30-Jun	***40***	***378***	***11***	***78***	***51***	***456***	***24,243***
1-Jul	11	66	5	30	16	96	24,339
2-Jul	7	42	11	66	18	108	24,447
3-Jul	58	348	7	*42*	65	*390*	24,837
4-Jul	202	1,212	***2***	***12***	***204***	***1,224***	***26,061***
5-Jul	164	984	290	1,740	454	2,724	***28,785***
6-Jul	179	1,074	***158***	***966***	***337***	***2,040***	30,825
7-Jul	26	156	71	426	97	582	31,407
8-Jul	36	216	74	444	110	660	32,067
9-Jul	12	72	21	126	33	198	32,265
10-Jul	41	246	201	1,206	242	1,452	33,717
11-Jul	16	96	122	732	138	828	34,545
12-Jul	22	132	67	402	89	534	35,079
13-Jul	13	78	37	222	50	300	35,379
14-Jul	23	138	78	468	101	606	35,985
15-Jul	10	60	52	312	62	372	36,357
16-Jul	0	0	4	24	4	24	36,381
17-Jul	7	42	7	42	14	84	36,465

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Table 5.–Page 2 of 2.

Date	East Channel		West Channel		Total		
	Daily Count	Daily Expanded/Interpolated	Daily Count	Daily Expanded/Interpolated	Daily Count	Daily Expanded/Interpolated	Cumulative Escapement
18-Jul	5	30	17	102	22	132	36,597
19-Jul	2	12	35	210	37	222	36,819
20-Jul	5	30	***33***	***204***	***38***	***234***	***37,053***
21-Jul	4	24	24	144	28	168	37,221
22-Jul	7	42	17	102	24	144	37,365
23-Jul	3	18	10	60	13	78	37,443
24-Jul	1	6	10	60	11	66	37,509
25-Jul	1	6	5	30	6	36	37,545
26-Jul	1	6	6	36	7	42	37,587
27-Jul	1	6	8	48	9	54	37,641
28-Jul	10	60	20	120	30	180	37,821
29-Jul	10	60	17	102	27	162	37,983
30-Jul	8	48	18	108	26	156	38,139
31-Jul	12	72	20	*120*	32	*192*	38,331
1-Aug	5	30	20	*120*	25	*150*	38,481
2-Aug	12	72	47	282	59	354	38,835
3-Aug	9	54	32	192	41	246	39,081
4-Aug	8	48	22	132	30	180	39,261
5-Aug	3	18	35	210	38	228	39,489
6-Aug	0	0	24	144	24	144	39,633
7-Aug	1	6	26	156	27	162	39,795
8-Aug	4	24	12	72	16	96	39,891
9-Aug	3	18	20	120	23	138	40,029
10-Aug	55	330	87	522	142	852	40,881
11-Aug	10	60	33	198	43	258	41,139
12-Aug	9	54	26	156	35	210	41,349
13-Aug	17	102	22	132	39	234	41,583
14-Aug	23	138	32	192	55	330	41,913
15-Aug	0	0	1	6	1	6	41,919
Totals	1,871	14,206	3,867	27,713	5,738	41,919	41,919

[a] To avoid splitting the diurnal pulses between adjacent calendar days a "count day" is defined as 1600 hours to 1500 hours; i.e. the 1 Aug count is passage that occurred from 1600 hrs 31Jul through 1500 hrs 1 Aug.

[b] Days for which interpolations were calculated are shaded and resulting changes in estimate numbers are shown in bold italics.

DISCUSSION

In 2005 and 2006, the relative precision of the escapement estimates exceeded the objective criteria (relative precision using α=0.05 was 0.13 in 2005 and 0.11 in 2006). Very few counting periods were missed in 2005, and potential bias associated with the interpolated estimates for the missed counting periods was likely negligible; However, the estimate for 2006 was based on interpolations for missed counts that represented approximately 30% of the total estimate. No counting was conducted during 10 of 12 days from 19–30 June, and based on run timing of Chinook salmon from 2002–2005, it is likely that these missed counts occurred when large numbers of fish were passing. The extent of the bias associated with interpolations for missed counts in 2006 is unknown, but there is the potential that it is large given the extent and timing of missed counting days. Additionally, it is unknown whether the variance estimates for the missed counting days adequately describe the uncertainty in salmon passage during those days. Variance for the missed days was approximated by assigning daily variances equal to the maximum observed variances from successful counting days before and after the missed days. It was believed that this approach would provide conservative estimates of variance (i.e., approximated variance was thought to be as large or larger than the true variance). However, because the missed counting days occurred during a peak-passage period, the approximated variance may have underestimated the true variance. As more years of escapement estimates and run timing data become available, alternative methods of interpolating escapement for missed counting days should be explored (e.g., based on average run timing).

The long-term goal of the project is to collect a sufficient time series of escapement estimates to establish an escapement goal to facilitate management of Chinook salmon in the Gulkana River. The existing Copper River drainage sustainable escapement goal (SEG) of 24,000 Chinook salmon facilitates management of the mixed stock commercial, subsistence, and personal-use fisheries, but does not stipulate any specific tributary goals. Furthermore, the inriver abundance estimates that are used to assess whether the SEG was met are not available inseason. Inseason catch per unit effort information can be used to assess run strength inseason, but only six years of information are currently available (2003–2008) and the interannual variation in catchability (ratio of catch to abundance) suggests that CPUE is a course measure of abundance.

Sustainable escapement goals (SEG) are set by ADFG when information regarding total return of a particular stock and the age composition of the return is lacking, as is the case with Gulkana River Chinook salmon. Typically, ADFG uses a percentile algorithm (Bue and Hasbrouck *Unpublished*) to set SEGs using observed escapement estimates. With this approach, a long time series of escapement estimates is required. More importantly, the time series should include a large contrast between the smallest and largest observed escapements. To date, five estimates of escapement are available (2002–2006). Estimates have ranged from 2,718 (2005) to 6,096 (2002) for a spawning contrast of 2.24. When setting escapement goals, ADFG does not have any specific criteria for the length of the escapement time series data or what constitutes an acceptable spawning contrast, but typically escapement goals are not set unless the escapement time series spans at least two generations for the species under consideration (approximately 10 years for Chinook salmon), and a spawning contrast exceeding 4.0 is most desirable. Escapement goal reviews by ADFG are conducted every three years. The review scheduled for 2011 will likely be the first opportunity to consider setting an escapement goal for Gulkana River Chinook salmon at which time 8 years (2002–2010) of escapement estimates will be available.

To estimate the total escapement of Chinook salmon upstream of the counting tower the number of Chinook salmon harvested above the tower must be known. The estimates of escapement in 2005 and 2006 assumed negligible sport harvests above the counting tower. In 2002 and 2003, estimates of sport harvest from the Statewide Harvest Survey (SWHS) were reported for all waters upstream of Sourdough Landing to Paxson Lake (Figure 1). This delineation was not adequate enough to determine the sport harvest above the counting tower. In 2004, the SWHS was modified to delineate two areas within this reach of the Gulkana River: Sourdough Landing to the West Fork confluence and the West Fork confluence to Paxson Lake. The estimated Chinook salmon harvest upstream of the West Fork was reported as zero in 2004, 306 in 2005, and 367 in 2006. It is believed that only a small fraction of this harvest occurred upstream of the counting tower. In 2007, further delineation was identified as "ADF&G Tower to West Fork" and "Paxson Lake to ADF&G Tower." Therefore, future tower and harvest estimates can be used to more accurately estimate escapement above the tower.

Even though all of the information needed to establish an escapement goal is not available at this time, enumeration of Chinook salmon migrating upstream of the counting tower should continue. Another goal of area sport fish management is to establish an inseason guideline to use for making a determination as to whether a management action (i.e., close the fishery) is needed to address low numbers of Chinook salmon. Continued estimates of escapement and run timing may indicate a number and corresponding date that could be used as a guideline. For example, if some number of Chinook salmon migrated past the counting tower by a particular date then no management action is required.

ACKNOWLEDGEMENTS

Partial funding for this project was provided by the Bureau of Land Management (BLM) The author would like to thank the ADF&G field crew and the BLM student technicians. Thanks go also to Elijah Waters and Mike Sondergaard, BLM, for their assistance with project logistics. Anton Antonovich completed the biometric review and Rachael Kvapil finalized the report for publication.

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